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POLYMERIC THICKENERS FOR OIL-CONTAINING COMPOSITIONS

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CROSS-REFERENCE TO RELATED APPLICATIONS

- 5 [0001] This invention is a continuation-in-part of copending, commonly assigned Application Serial No. 09/398,377, filed Sept. 17, 1999, by Steven P. Bitler. The entire disclosure of that application is incorporated herein by reference for all purposes. This application also claims priority from International Application No. PCT/U.S. 00/40780, filed August 30, 2000.

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BACKGROUND OF THE INVENTION

Field of the Invention

- 15 [0002] This invention relates to polymeric thickeners for oil-containing compositions.

Introduction to the Invention

- 20 *See Q' >* [0003] ~~U.S. Patent Nos. 4,057,622, 4,057,623, 4,057,624, 5,318,995, 5,519,063, and 5,736,125 disclose the possibility of thickening oil-containing compositions with certain polymers containing (a) lipophilic groups (e.g. in units derived from long chain n-alkyl acrylates) and (b) certain other groups, namely amido groups (in units derived from acrylamide), pyrrolidino groups (in units derived from N-vinyl pyrrolidone), imidazole groups (in units derived from N-vinyl imidazole), carboxylic acid and~~
25 ~~carboxylic acid salt groups (e.g. in units derived from acrylic or methacrylic acid),³ sulfonic acid groups, and sulfonic acid salt groups. Japanese Kokai No. 4-10054 discloses non-aqueous compositions containing (A) a fluoropolymer containing a perfluoroalkyl group and an alkyl group, either or both of which may be a long chain~~
~~group, (B) a liquid perfluoroalkyl-organic compound, and (C) an oil.~~

P.S.
11/24/02

SUMMARY OF THE INVENTION

[0004] We have discovered, in accordance with present invention, that a broad range of side chain crystalline (SCC) polymers can be used to thicken oils, provided that the SCC polymer will dissolve in the oil at a temperature above the crystalline melting point of the polymer (referred to herein as T_p) and will crystallize when the solution of the polymer in the oil is cooled to a temperature which is below T_p and at which the thickened oil composition is to be used. We believe, though the invention is not dependent upon the correctness of our belief, that the SCC polymer crystallizes into a network in which the polymer crystallites are connected to one another by semi-soluble chains.

[0005] The SCC polymers used in the present invention contain lipophilic groups, for example long chain alkyl or substituted alkyl groups, and can, but do not necessarily, contain one or more other groups. They are however, substantially free of fluorine atoms, carboxylic acid groups, carboxylic acid salt groups, sulfonic acid groups, sulfonic acid salt groups, amido groups, pyrrolidino groups and imidazole groups. The term "substantially free" of these groups is used herein to mean that each of the following conditions is fulfilled by the SCC polymer:

- (1) at most 2%, preferably at most 1%, particularly none, of the carbon atoms are substituted by one or more fluorine atoms;
- (2) at most 0.5 mol%, preferably at most 0.2 mol%, particularly none, of the repeating units contain a carboxyl group, a carboxyl salt group, a sulfonic acid group, or a sulfonic acid salt group;
- (3) at most 1%, preferably at most 0.5%, particularly none, by weight of the repeating units contain a carboxyl group, a carboxyl salt group, a sulfonic acid group, or a sulfonic acid salt group;
- (4) the polymer has an acidity of less than 0.1, preferably less than 0.07, meq/g;
- (5) at most 2 mol%, preferably at most 1 mol%, particularly none, of the repeating units are derived from acrylamide;

(6) at most 0.5 mol%, preferably at most 0.2 mol%, particularly none, of the repeating units are derived from N-vinylpyrrolidone;

(7) at most 0.5 mol%, preferably at most 0.2 mol%, particularly none, of the repeating units are derived from N-vinylimidazole.

5 If the SCC polymer contains a substantial number of fluorine atoms, it is more difficult to dissolve in the oil, and this often makes it necessary to add a surfactant in order to achieve solution.

[0006] In a first aspect, this invention provides a thickened oil composition which is at
10 a temperature T_s and which comprises

(1) an oil, and

(2) uniformly dispersed in the oil as a crystallized solid, a side chain
crystalline (SCC) polymer which

15 (a) has a crystalline melting point, T_p , which is greater than T_s , and

(b) is substantially free of fluorine atoms, carboxylic acid groups,
carboxylic acid salt groups, sulfonic acid groups, sulfonic acid salt groups,
amido groups, pyrrolidino groups and imidazole groups.

The composition should be maintained at a temperature below T_p , since the polymer will
have a much reduced thickening effect if it redissolves in the oil. The composition can
20 be free of water, or can contain water. For example it can be a water-in-oil emulsion.

[0007] In a second aspect, this invention provides a thickened oil composition which
comprises

(1) an oil, and

25 (2) dispersed in the oil, a polymer which

(a) has a crystalline melting point, T_p , and an onset of melting
temperature, T_o , such that $T_p - T_o$ is less than $T_p^{0.7}$;

(b) is soluble in the oil at temperatures above T_p ,

(c) has been dispersed in the oil by a process which comprises

30 (i) dissolving the polymer in the oil at a temperature above
 T_p , and

(ii) cooling the solution to crystallize the polymer in the oil,
and

(d) is a side chain crystalline (SCC) polymer which is
substantially free of fluorine atoms, carboxylic acid groups,
carboxylic acid salt groups, sulfonic acid groups, sulfonic acid salt
groups, amido groups, pyrrolidino groups and imidazole groups;
the composition being at a temperature T_s which is below T_p .

[0008] In a third aspect, this invention provides a method of making a composition
according to the first or second aspect of the invention, the method comprising

- (i) dissolving the SCC polymer in the oil at a temperature above T_p , and
- (ii) cooling the solution to crystallize the polymer in the oil.

An advantage of using these SCC polymers as thickening agents, particularly in
water-in-oil emulsions, is that the need to use a surface active agent is reduced or
removed. Thus the compositions preferably contain less than 5%, more preferably less
than 2%, particularly less than 1%, especially substantially 0%, of surface active agents,
the percentages being by weight based on the weight of the oil. This is particularly
useful in cosmetic and personal care products, since it is conventional for such products
to contain surface active agents (for example the perfluoroalkyl organic compounds
used in the compositions disclosed in Japanese Kokai No. 4-100534), and surface
active agents can cause an adverse reaction when they contact human skin.

DETAILED DESCRIPTION OF THE INVENTION

[0009] In the Summary of the Invention above, and in the Detailed Description of the
Invention, the Examples, and the Claims below, reference is made to particular features
of the invention. It is to be understood that the disclosure of the invention in this
specification includes all appropriate combinations of such particular features. For
example, where a particular feature is disclosed in the context of a particular
embodiment or a particular claim, that feature can also be used, to the extent

appropriate, in the context of other particular embodiments and claims, and in the invention generally.

Definitions and Abbreviations

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[00010] In this specification, parts and percentages are by weight, except where otherwise noted. Temperatures are in °C. The onset-of-melting temperature, T_o , the peak melting temperature, T_p , and the heat of fusion, J/g, are determined using a differential scanning calorimeter (DSC) at a rate of temperature change of 10 °C./min, for example from -10 to 150 °C., and on the second heat cycle. T_p is the temperature at the peak of the DSC curve, and T_o is the temperature at the intersection of the baseline of the DSC peak and the onset line, the onset line being defined as the tangent to the steepest part of the DSC curve below T_p . The abbreviations M_n and M_w are used to denote number average and weight average molecular weight in daltons, respectively, measured in tetrahydrofuran using size exclusion chromatography, configured with a Wyatt laser light scattering detector. Bulk viscosities given in the Examples for the polymeric thickeners are in centipoise and were measured using a Brookfield LVT viscometer with an electrically thermostatted Thermosel heater, controlled for example to 95 °C., and small sample adapter using spindles 4 and 7.

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[00011] The abbreviation CxA is used to denote an n-alkyl acrylate in which the n-alkyl group contains x carbon atoms, the abbreviation Cx alkyl is used to denote an n-alkyl group which contains x carbon atoms, and the abbreviation CxM is used to denote an n-alkyl methacrylate in which the n-alkyl group contains x carbon atoms. Other abbreviations are given elsewhere in the specification.

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[00012] The procedures used in the Examples to compare the effectiveness of the polymeric thickeners were as follows. In Examples 1-8, the thickener, 5 parts, was dissolved in hydrogenated polyisobutylene (HPIB, a light oil), 95 parts, with stirring at 120 °C. The resulting solution was placed in an incubator at 20 °C. for 16 hours. The viscosity of the cooled product in centipoise was determined using a Brookfield DV-I+

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digital viscometer with CP-51 spindle using a sample adapter which was thermostatically controlled, for example, to 25 °C. The viscosities were measured after four minutes at a speed of 2.5 rpm, i.e. after 10 revolutions. In Examples 9-17, the oil (as identified in Table 2), 14 parts, was heated to 80 °C., and the thickener, 0.75 part, was dissolved therein. Water, 35 parts, containing $\text{MgSO}_4 \cdot \text{H}_2\text{O}$, 0.25 part, was heated to 80 °C. The oil and the water, both at 80 °C, were mixed together, and then cooled to 25 °C. with continued stirring. The product, a milky white water-in-oil emulsion, was left overnight, and its viscosity at 25 °C. was then measured using a Brookfield cone and plate viscometer. The viscosity was measured after 0.5, 1, 2 and 4 minutes, to assess the effect of shear on the emulsion.

The Polymeric Thickeners

[00013] The SCC polymers used as thickeners in the present invention can be homopolymers, or copolymers of two or more comonomers, including random copolymers, graft copolymers and block copolymers (including thermoplastic elastomers). Two or more SCC polymers can be used together. The number average molecular weight of the SCC polymer is generally from 10,000 to 1,500,000, preferably 12,000 to 1,000,000. The molecular weight of an SCC polymer is relatively unimportant to its T_p , but is generally an important factor in determining the T_p of other polymers.

[00014] The SCC polymer preferably melts over a relatively small temperature range. The closer T_p is to room temperature, the more rapid the transition should preferably be. The SCC polymer preferably has an onset of melting temperature, T_o , such that $T_p - T_o$ is less than $T_p^{0.7}$, generally less than $T_p^{0.6}$, particularly less than 10 °C., especially less than 6 °C., T_o and T_p being in °C. The crystallinity of the SCC polymer is preferably such that its heat of fusion is at least 20 J/g, particularly at least 40 J/g.

[00015] The SCC polymers used in the present invention are in themselves well known. Publications describing SCC polymers include U.S. Patent Nos. 4,830,855, 5,120,349, 5,156,911, 5,387,450, 5,412,035, 5,665,822, 5,783,302, 5,752,926,

5,807,291, 5,469,867, and 5,826,584; J. Poly. Sci. 60, 19 (1962), J. Poly. Sci. (Polymer Chemistry) 7, 3053 (1969), 9, 1835, 3349, 3351, 3367, 10, 1657, 3347, 18, 2197, 19, 1871, J. Poly. Sci, Poly-Physics Ed 18 2197 (1980), J. Poly. Sci, Macromol. Rev, 8, 117 (1974), Macromolecules 12, 94 (1979), 13, 12, 15, 18, 2141, 19, 611, JACS 75, 3326 (1953), 76; 6280, Polymer J 17, 991 (1985); and Poly. Sci USSR 21, 241 (1979). The entire disclosure of each of these United States Patents is incorporated in this specification by reference.

[00016] The SCC polymer may for example be derived from one or more acrylic, methacrylic, olefinic, epoxy, vinyl, ester-containing, amide-containing or ether-containing monomers. Preferred SCC polymers comprise repeating units in which the side chains comprise linear polymethylene radicals containing 10 to 50, e.g. 16-50, especially 16 to 22, carbon atoms. Polymers containing such units can be prepared by polymerizing a monomer component comprising one or more corresponding linear aliphatic acrylates or methacrylates, or equivalent monomers such as acrylamides or methacrylamides. A number of such monomers are available commercially, either as individual monomers or as mixtures of identified monomers, for example C12A, C14A, C16A, C18A, C22A, a mixture of C18A, C20A and C22A, and a mixture of C26A to C40A. The polymers may also contain units derived from one or more other comonomers, for example straight or branched chain alkyl acrylates or methacrylates in which the alkyl group contains less than 12 carbon atoms, and monomers containing suitable functional groups, for example functional groups containing oxygen-, nitrogen- or silicon-containing groups, provided that the polymer is substantially free of fluorine atoms, carboxylic acid groups, carboxylic acid salt groups, sulfonic acid groups, sulfonic acid salt groups, amido groups, pyridino groups, and imidazole groups. Such monomers includes those listed below. In the list below, the term (meth)acrylate means that the compound may be either an acrylate or a methacrylate.

- (a) Nitrogen-containing monomers, for example N,N-dialkylamino (in particular, dimethylamino) (meth)acrylates; ammonium salt-containing (meth)acrylates, for example 2-trimethylammonium methylmethacrylate chloride, methacrylamidopropyl trimethylammonium chloride, N,N- (diethyl or

dimethyl)aminoethyl(meth)acrylate methosulfate; imides like the ring-closed reaction products of maleic or itaconic anhydride with primary amines; 2-methacryloxy-N-ethylmorpholine; 2-t-butylaminoethyl methacrylate; (meth)acrylonitrile; t-butylaminoethyl (meth)acrylate; acryloylmorpholine; N-(2-hydroxyethyl)acetamide and 1-piperidinoethyl (meth)acrylate.

(b) Oxygen-containing monomers which are substantially free of carboxylic acid groups, carboxylic acid salt groups, sulfonic acid groups, sulfonic acid salt groups, and amido groups, for example hydroxyalkyl (in particular, hydroxyethyl, hydroxypropyl, and hydroxybutyl) (meth)acrylates; tetrahydrofurfuryl (meth)acrylate; glycidyl methacrylate; alkoxyalkyl (meth)acrylate, e.g. methoxyethyl (meth)acrylate; 1-acryloxy-2-hydroxy-3-phenoxypropane; methylol methacrylate; ethoxyethyl (meth)acrylate; 2-(2-ethoxyethoxy)ethylacrylate; acetoacetoxyethyl (meth)acrylate; phenoxyethyl (meth)acrylate and (meth)acrolein.

(c) Silicon-containing, e.g. silyl, monomers, for example trimethylsiloxy ethyl(meth)acrylate, 3-acryloxypropyl trimethoxysilane, and 3-acryloxypropyl tris(trimethylsiloxy)silane.

[00017] When the SCC polymer is a graft or block copolymer, it can be prepared by copolymerizing a vinyl type macromonomer with other monomers, or by making an SCC polymer, and then reacting the functionalized polymer with the second block material, for example a urethane block, an epoxy block, a polyether block, e.g. a polyethyleneoxide, polypropyleneoxide or polytetramethyleneoxide block, a polysiloxane block, or a poly(alkyl or alkoxy)silane block.

[00018] The SCC polymer should contain sufficient long chain groups that it will dissolve in the oil at a temperature above T_p . When the SCC polymer is used to thicken an oil or mixture of oils which is free from water, the polymer generally contains at least 50 %, preferably at least 60%, particularly at least 70%, especially at least 80%, of units comprising a linear radical containing 10 to 50 carbon atoms, and can contain up to

100% of such units. Particularly when the SCC polymer is used to thicken a water-in-oil emulsion, it may contain at least 5%, preferably at least 10%, of units derived from a monomer containing a hydrophilic group, preferably a hydroxyl group, and may contain higher amounts, e.g. up to 25% or 30%, provided that the SCC polymer will dissolve in the oil.

[00019] In one preferred embodiment, the SCC polymer consists essentially of

- (i) 70-99% by weight of repeating units derived from at least one n-alkyl acrylate or methacrylate ester in which the n-alkyl group contains 16 to 22 carbon atoms,
- (ii) 1-30%, preferably 15-25%, by weight of repeating units derived from at least one acrylate or methacrylate ester in which the ester group contains a hydroxyl-substituted alkyl group containing less than 12 carbon atoms, and
- (iii) 0-30% by weight of repeating units derived from at least one acrylate or methacrylate ester in which the ester group contains an unsubstituted alkyl group containing less than 16 carbon atoms.

Suitable polymers within this class include SCC polymers consisting essentially of

- (i) 70-99% by weight of the repeating units derived from at least one n-alkyl acrylate or methacrylate ester in which the n-alkyl group contains 16 to 22 carbon atoms, and
- (ii) 1-30%, preferably 15-25%, by weight of the repeating units derived from at least one acrylate or methacrylate ester in which the ester group contains a hydroxyethyl, hydroxypropyl, or hydroxybutyl group.

[00020] The molecular weight (and other properties) of the SCC polymer should be sufficiently high that the polymer, after it has been dissolved in the oil, will crystallize in the oil when the heated mixture is cooled to the expected temperature of use, for example to a temperature 10-20 °C. below T_p , thus producing an opaque mixture.

[00021] The T_p of the thickening polymer is preferably 10-40 °C. above, particularly 10-30 °C. above, especially about 20 °C. above, the temperature at which the

composition is to be used, which is generally 15-25 °C. It appears that the oil plasticizes the thickening polymer, so that its melting point in the composition is for example 5-10 °C. lower than T_p . It is therefore important that T_p is sufficiently above the temperature of use to ensure that the thickening polymer does not melt during use.

- 5 Thus for compositions to be used at 20-25 °C. the thickening polymer preferably has a T_p of above 40 °C., preferably 40-50 °C. On the other hand, if the T_p of the thickening polymer is too far above the temperature of use, this can result in excessive crystallization and then precipitation of the polymer, thus reducing the thickening effect. It is preferred, therefore, that T_p is not more than 30 °C. above, preferably not more than
- 10 20 °C. above, the temperature of use. Depending on the expected temperature of use, T_p may be from 0-150 °C. generally 10-100 °C., for example 40-80 °C., preferably 40-50 °C. , particularly 43-48 °C.

Dr. B17
~~[00022] The amount of the polymeric thickener preferably used varies with the~~
15 application. It is usually unnecessary for the amount of the thickener to be more than 10% by weight based on the weight of the oil. Smaller amounts such as 2 to 7% based on the weight of the oil in compositions which are free of water, and 0.5 to 5% based on ~~the weight of composition in water-in-oil emulsions, are often effective.~~

20 Oils

Dr. A2
~~[00023] The new polymeric thickeners are effective with a broad range of oils.~~
Suitable oils are disclosed, for example, at column 3, line 37, to column 4, line 4, of U.S. Patent No. 5,736,125. For thickening silicone oils, it is preferred to use an SCC polymer
25 containing units derived from a monomer containing silicon, for example a block copolymer containing SCC blocks and polysiloxane blocks. SCC/polysiloxane polymers ~~of this type are described for example in WO 93/07194 and WO 00/04787.~~

Water-in-oil Emulsions

[00024] Water-in-oil emulsions are preferably prepared by mixing together (1) a hot solution of the thickener in the oil and (2) the aqueous phase, the aqueous phase being at a temperature similar to the oil solution (e.g. not more than 10 °C. different); and then cooling the mixture while stirring. The ratio of the aqueous phase to the oil phase can be for example 0.5:1 to 9:1.

Compositions

[00025] The invention is particularly useful for personal care compositions, for example cosmetics, toiletries, and cleansers, including but not limited to lipsticks, deodorant sticks, nail varnishes, creams, gels and oils, including sun creams, protective hand creams, night renewal creams, body milks and lotions, light facial cream, protective day cream, liquid moisturizing emulsions, oil-in-water creams and water-in-oil creams, as well as thickened oil products with or without water and products designed to assist in removing other cosmetic, makeup or personal care products. The invention is also useful in other contexts, for example in paints, film-forming compositions, inks, and compositions carrying active ingredients such as UV absorbers, fragrances, biocides, antimicrobial agents, germicides, antioxidants, preservatives, disinfectants, enzymes, nutrients, minerals, and drugs (including pharmaceuticals which are active physiologically or pharmacologically, either topically or systemically). Compositions containing a thickener containing an ammonium salt are likely to be useful in certain types of hair care compositions.

[00026] The invention is illustrated by the following Examples.

Examples

[00027] Polymers and copolymers were made using the ingredients and amounts thereof shown in the Table below, using the following generalized method. To a resin kettle equipped with overhead stirrer and condenser was added 20% of the monomers and chain transfer agents. The mixture in the resin kettle was heated to 110 °C., and

oxygen was removed from the system through nitrogen purge for about 30 min followed by addition of 20% of the starting initiator charge. After allowing sufficient time for any initial exotherm to abate, the remaining monomers, chain transfer agents and starting initiator were pumped into the reaction vessel over 60-90 min. The polymer mixture was allowed to continue reacting for 60 min followed by addition of the chase initiator and reaction for 60 min. The mixture was put under reduced pressure for 60 min to removal volatile residuals. The resulting polymers were generally yellow to white solids. The molecular weight, T_p , and viscosity of each sample were measured. The effectiveness of the polymers as thickeners was measured as described above, and the results are shown in Tables 1 and 2 below.

[00028] The following abbreviations are used in the Tables. ME = mercaptoethanol; MA = methacrylic acid; DMAEA = N,N-dimethylaminoethyl acrylate; HEA = 2-hydroxyethyl acrylate; TAPO = t-amylperoxy 2-ethylhexanoate sold by Witco as Esperox 570P, 75% active in liquid; TBPB = t-butylperoxybenzoate sold by Witco as Esperox 10; Estol is propylene glycol dicaprylate/caprate sold by Uniqema under the tradename Estol 1526; Min'l is mineral oil; and opq = opaque in appearance.

TABLE 1

Example	1	2	3	4	5	6
C16A				95		
C18A	80		95		100	85
C22A		95				
HEA	20					
DMAEA						15
MA		5	5	5		
ME	0.34	0.17	0.17	0.17	0.17	0.1
TAPO	1.73	1.73	1.73	1.73	1.73	1.73
TAPB	0.67	0.67				
TBPB			0.5	0.5	0.5	0.5
T _p °C.	48	67	47	39	50	45
J/g	56	99	57	64	73	60
M _w	236K		427K	1,000K	950K	
M _n	52K		240K	520K	230K	
Bulk viscosity	4,000	2,500	19,000	24,000	2,000	350
Visc in HPIB	12,600 opq	164 opq	2600 opq	<50 clear	5400 opq	6000 opq

- 5 [00029] In Example 2, the polymer had a T_p above the preferred range of 40-50 °C., which resulted in excessive crystallinity and poor thickening under the test conditions. In Example 4, the polymer had a T_p below the preferred range, and was ineffective as a thickener under the test conditions, because it did not crystallize on cooling.

TABLE 2

Example	7	8	9	10	11	12
C18A	80	80	80	100	100	100
HEA	20	20	20			
ME	0.34	0.34	0.34	0.17	0.17	0.17
TAPO	1.73	1.73	1.73	1.73	1.73	1.73
TAPB	0.67	0.67	0.67			
TBPB				0.5	0.5	0.5
Tp °C.	48	48	48	50	50	50
J/g	56	56	56	73	73	73
Mw	236K	236K.	236 K	950 K.	950 K.	950 K.
Mn	52K	52 K.	52 K.	230 K.	230 K.	230 K.
Bulk viscosity	4,000	4,000	4,000	2,000	2,000	2,000
Oil	HPIB	Min'l	Estol	HPIB	Min'l	Estol
Viscosity after						
0.5 min	35K	37K	45K	29K	**	**
1.0 min	35K	38K	40K	28K		
2.0 min	41K	38K	34K	25K		
4.0 min	46K	40K	34K	28K		

** separated.

- 5 [00030] The invention has been described by reference to the use of SCC polymers. However, other polymers with the same crystallinity characteristics give similar results, and their use as thickeners for oils forms part of the present invention. Such other polymers include for example polymers in which the crystallinity results exclusively or predominantly from the polymer backbone, e.g. polymers of α -olefins
- 10 containing 2 to 12, preferably 2 to 8, carbon atoms, e.g. polymers of monomers having the formula $\text{CH}_2 = \text{CHR}$, where R is hydrogen, methyl, propyl, butyl, pentyl, 4-methylpentyl, hexyl or heptyl, as well as other polymers such as polyesters, polyamides, for example homopolymers and copolymers of caprolactone, and polyalkylene oxides, for example polytetrahydrofuran.